35.G1008

PATENT APPLICATION

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:	)	
	:	Examiner: Unknown
NAOKI NISHIMURA, ET AL.	)	
	:	Group Art Unit: 1509
Serial No.: 08/111,974	)	
	:	
Filed: August 26, 1993	)	
	:	
For: A MAGNETOOPTICAL RECORDING MEDIUM AND INFORMATION RECORDING AND REPRODUCING METHODS USING THE RECORDING MEDIUM	) :) :) :	December 15, 1993

The Honorable Commissioner of Patents
and Trademarks
Washington, D.C. 20231

CLAIM TO PRIORITY

Sir:

Applicants hereby claim priority under the International Convention and preserve all rights to which they are entitled under 35 U.S.C. § 119 based on the following Japanese Patent Applications:

04-230277, filed August 28, 1992;
04-230266, filed August 28, 1992;
04-230265, filed August 28, 1992;
05-038138, filed February 26, 1993;
05-038137, filed February 26, 1993;
05-043786, filed March 4, 1993;
05-066656, filed March 25, 1993;
05-098025, filed April 23, 1993;
05-188438, filed July 29, 1993; and
05-188400, filed July 29, 1993.

Certified copies of the priority documents are enclosed.

Applicants' undersigned attorney may be reached in our Washington, D.C. Office by telephone at (202) 347-8100. All correspondence should continue to be directed to our below-listed address.

Respectfully submitted,

____

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PATENT OFFICE
JAPANESE GOVERNMENT

別紙添付の書類に記載されている事項は下記の出願書類に記載されて
る事項と同一であることを証明する。

his is to certify that the annexed is a true copy of the following application as filed
this Office.

願 年 月 日
e of Application:　　　１９９２年　８月２８日

願 番 号
lication Number:　　　平成　４年特許願第２３０２６５号

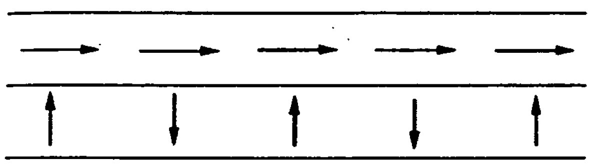
願 人
cant (s):　　　キヤノン株式会社

１９９３年１０月　８日

特許庁長官
Commissioner,
Patent Office　　　麻生渡

【書類名】　図面

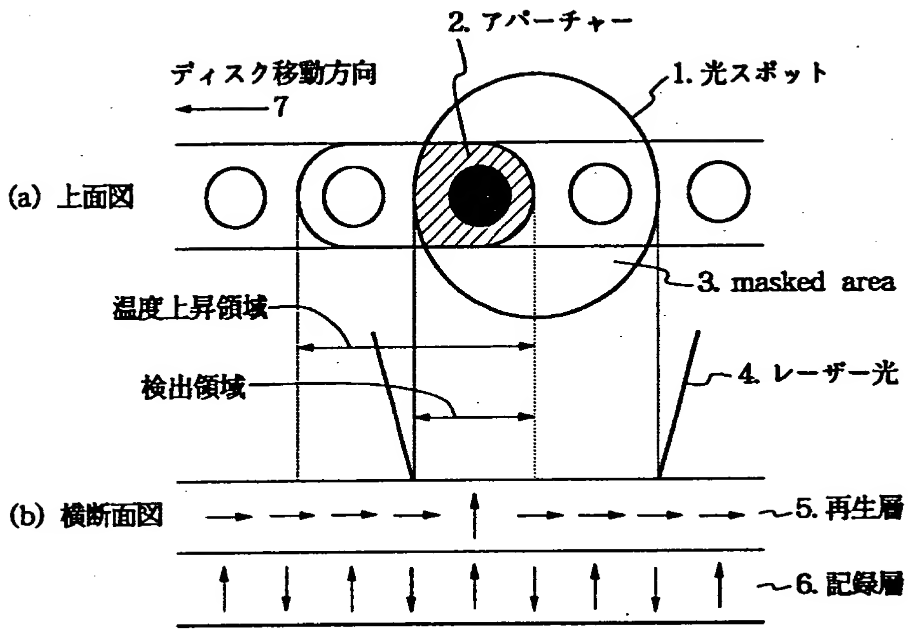
【図1】



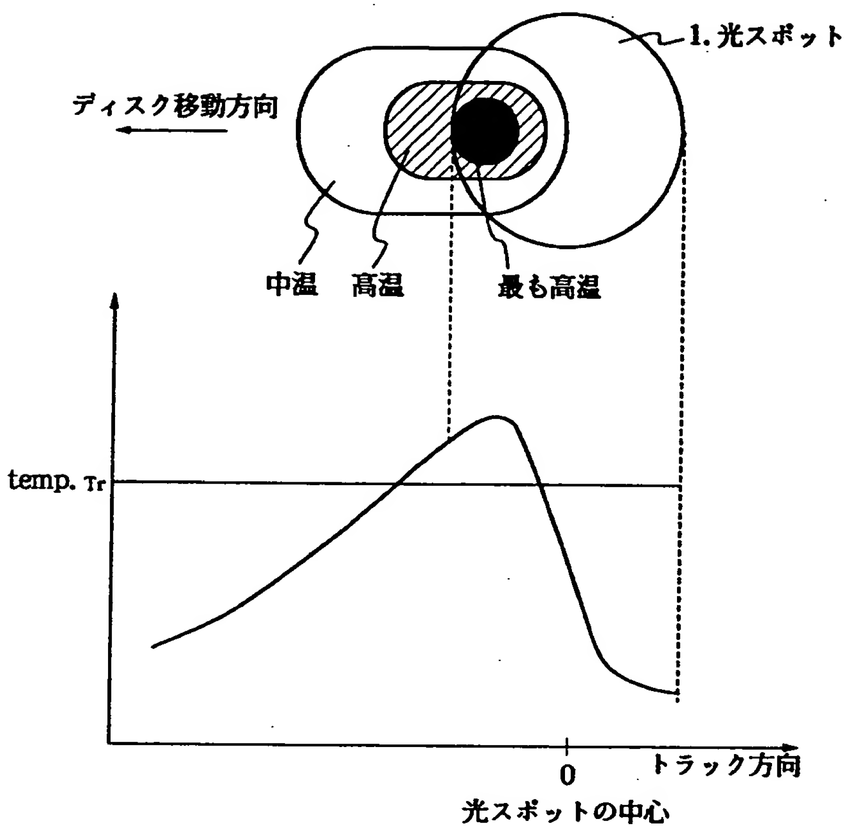
1. 面内磁化膜（再生層）

2. 垂直磁化膜（記録層）

【図2】


2. アパーチャー
ディスク移動方向
7
1. 光スポット
(a) 上面図
3. masked area
温度上昇領域
検出領域
4. レーザー光
(b) 横断面図
5. 再生層
6. 記録層

【図3】



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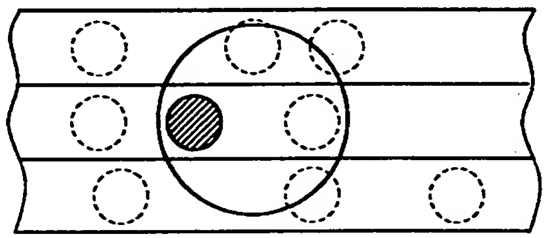

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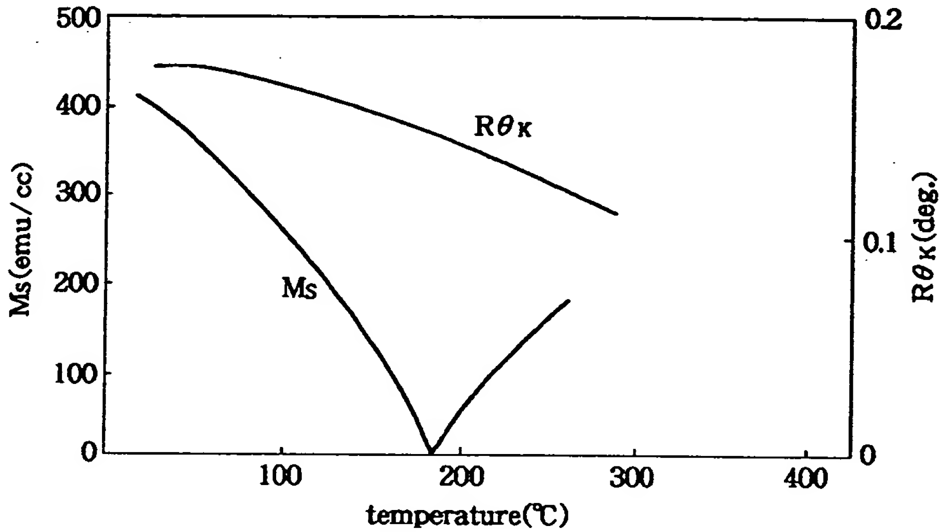
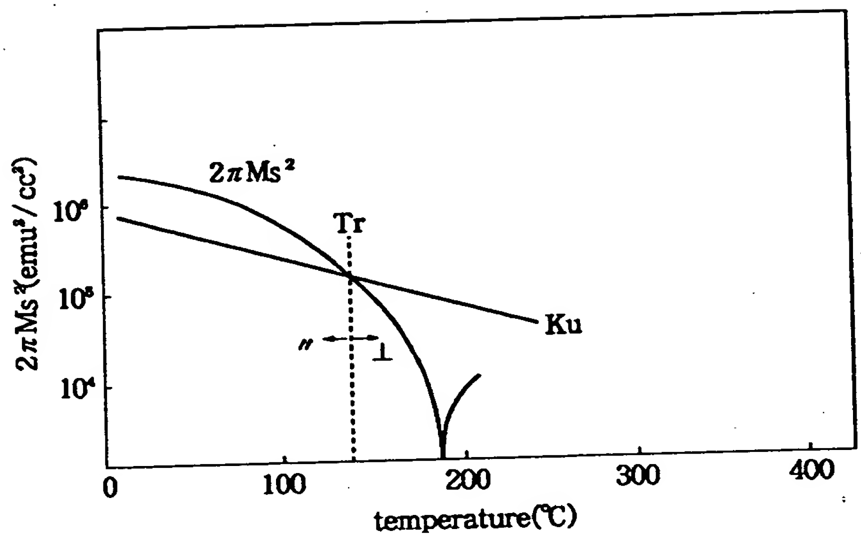
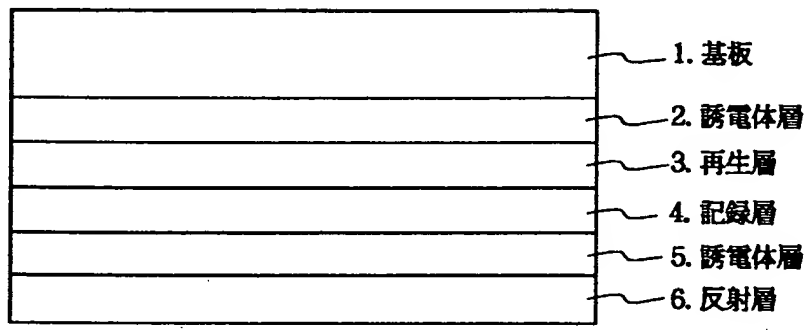


500
400
300
200
100
0
Ms(emu/cc)
0.2
0.1
0
Rθκ(deg.)
Rθκ
Ms
100
200
300
400
temperature(℃)

6】


2πMs²
Tr
Ku
//
⊥
10⁶
10⁵
10⁴
2πMs²(emu²/cc²)
0
100
200
300
400
temperature(℃)

【7】



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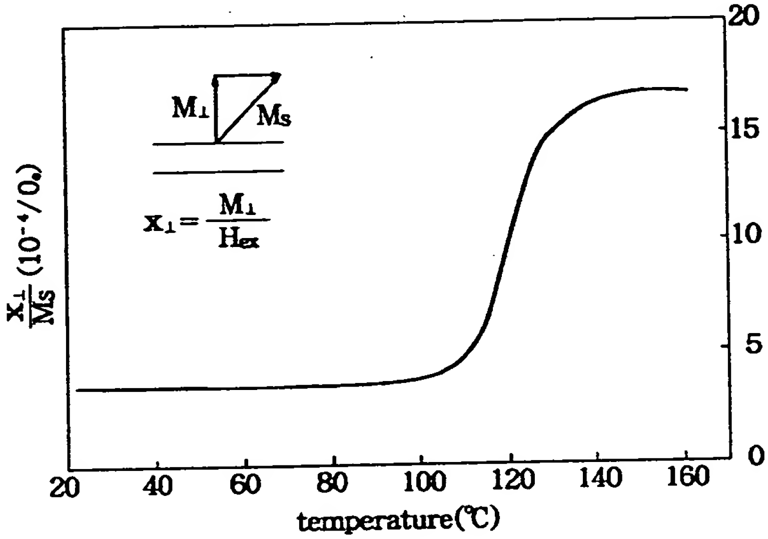
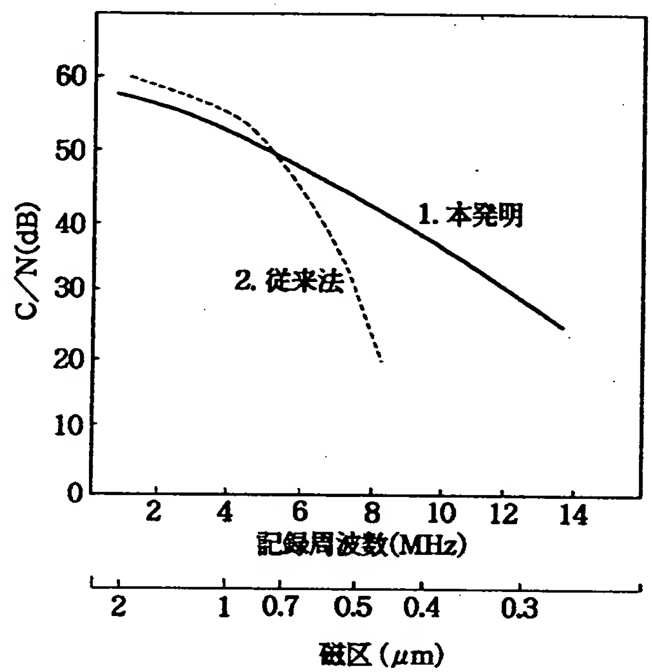


M⊥
Ms
x⊥ = M⊥ / Hex
x⊥ / Ms (10⁻⁴/Oe)
20
15
10
5
0
20
40
60
80
100
120
140
160
temperature(℃)

【図9】


C／N(dB)
60
50
40
30
20
10
0
1. 本発明
2. 従来法
2
4
6
8
10
12
14
記録周波数(MHz)
2
1
0.7
0.5
0.4
0.3
磁区(μm)

[Document type]	Patent application
[Reference No.]	2326018
[Date of submission]	August 28, 1992
[Submitted to]	Mr. Wataru Aso Commissioner, Japanese Patent Office
[IPC]	G11B 11/10
[Title of the invention]	
	Magneto-optical recording medium and reproduction method of the same
[Number of claims]	2
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[Charge article]	
[Mode of payment]	deposit
[Deposit A/C No.]	011224
[Amount of deposit]	14000
[List of submitted documents]	
[Name]	Specification 1

[Name]	Drawings	1
[Name]	Abstract	1
[General power of attorney No.]		9003707
[Proof necessity]	necessary	

[Document type] Specification

[Title of the invention]

Magneto-optical recording medium and reproduction method of the same

[Claims]

1. A method of reproducing signals on a magneto-optical recording medium, which uses a magneto-optical recording medium, said magneto-optical recording medium comprising: a first magnetic layer which is an in-plane magnetized film at room temperature but which changes into a perpendicular magnetized film when the layer is heated; and a second magnetic layer composed of a perpendicular magnetized film,

wherein said first magnetic layer is heated by irradiation of laser beams, thus changing said first magnetic layer into the perpendicular magnetized film, and

magnetic signals recorded on said second magnetic layer are converted into optical signals by means of magneto-optical effect and read out, while transcribing the magnetic signals onto the first magnetic layer.

2. A magneto-optical recording medium, characterized by comprising:

a first magnetic layer which is an in-plane magnetized film at room temperature but which changes into a perpendicular magnetized film when the layer is heated; and

a second magnetic layer composed of a perpendicular magnetized film.

[Detailed description of the invention]

[Applicable industrial field of the invention]

[0001] The present invention relates to a magneto-optical recording medium for recording and reproducing information with laser beams by use of magneto-optical effect and a reproduction method of the medium, more specifically, to a magneto-optical recording medium effectuating high densification of the medium by improving linear recording density and track density thereof, and to a reproduction method of the medium.

[Prior art]

[0002] A magneto-optical recording medium, which records information by means of writing magnetic domains into a magnetic thin film using thermal energy of a semiconductor laser and reads the information out by use of

magneto-optical effect, is drawing attention as a rewritable high-density recording medium.

[0003] In recent years, demands are increasing for enhancing recording density of the magneto-optical recording medium to obtain a recording medium of higher capacity.

[0004] Incidentally, linear recording density of an optical disc such as the magneto-optical recording medium is mainly decided by S/N of a reproduction layer, and a signal quantity of the reproduction layer largely depends on bit array cycles of recorded signals, a laser wavelength of a reproductive optical system, and the number of apertures of an objective lens.

[0005] Accordingly, when the laser wavelength λ of the reproductive optical system and the number of the apertures of the object lens NA are decided, a bit cycle f as a detection limit is decided as follows:

[0006]

$$f = \lambda / 2NA$$

Meanwhile, track density is restricted mainly by cross talks. The cross talk is decided mainly by distribution (a profile) of the laser beams on a surface of the medium, and it is expressed similarly to the above-mentioned bit cycle by the function $\lambda / 2NA$.

[0007] Therefore, in order to realize high densification with a conventional optical disc, it is necessary to shorten the laser wavelength of the reproductive optical system and to increase the number of the apertures of the objective lens NA.

[0008] However, improvements in the laser wavelength and the number of the apertures of the objective lens also have limitations. For this reason, technologies for improving the recording density by way of contriving a constitution of the recording medium or a method of reading have been developed.

[0009] For example, Japanese Patent Laid-Open Publication Hei 3 (1991) – 93058 attempts to improve recording density and track density by using a medium composed of a reproduction layer and a record layer, and reducing intersymbol interference upon reproduction by aligning the orientation of magnetization of the reproduction layer prior to reproduction of signals and then transcribing the signals held in the record layer to the reproduction

layer, thus effectuating reproduction of the signals of which cycles are not higher than diffraction-limited of light.

[Problems to be solved by the invention]

[0010] Nevertheless, according to the method of magneto-optical reproduction described in Japanese Patent Laid-Open Publication Hei 3 (1991) – 93058, magnetization of the reproduction layer needs to be oriented to a certain direction prior to irradiation of laser beams. For this reason, a conventional device requires addition of a magnet for initialization of the reproduction layer. Accordingly, the above-described reproduction method has problems such as complication of magneto-optical recording devices, cost increases, and difficulty in downsizing.

[Means to solve the problems]

[0011] In consideration of the above-described problems, an object of the present invention is to provide a magneto-optical recording medium which enables a magneto-optical recording and reproducing device being used conventionally to reproduce signals of which cycles are not higher than diffraction-limited of light and to improve linear recording density and track density thereof by dispensing a reproduction layer from initialization, and to provide a reproduction method of the medium.

[0012] The above-mentioned object is achieved: with use of a magneto-optical recording medium composed of a reproduction layer, which is an in-plane magnetized film at room temperature but changes into a perpendicular magnetized film when it is heated, and a record layer made of a perpendicular magnetized film, by recording signals on the above-described record layer; and then upon signal reproduction, by converting the magnetization of the record layer into optical signals by means of magneto-optical effect and read out, while transcribing the magnetization to the reproduction layer.

[0013] Moreover, the object is achieved by a magneto-optical recording medium composed of a reproduction layer, which is an in-plane magnetized film at room temperature but changes into a perpendicular magnetized film when it is heated, and a record layer made of a perpendicular magnetized film.

[Embodiment]

[0014] Now, the present invention will be described in detail with reference

to the accompanying drawings.

[0015] Fig. 1 is a schematic view showing one example of film compositions of a magneto-optical recording medium of the present invention. Fig. 2 is an explanatory view for showing a principle of a reproduction method of the magneto-optical recording medium of the present invention. Fig. 3 is a schematic view showing temperature distribution of a medium around a beam spot when the medium is moved. Fig. 4 is a schematic view showing a state of emergence of magnetization transcription. Fig. 5 is a view showing one example of temperature dependency of magnetization Ms and a performance index ($R\theta_k$) of the reproduction layer. Fig. 6 is a view showing one example of temperature dependency of $2\pi Ms^2$ and a perpendicular magnetic anisotropy constant Ku of the reproduction layer.

[0016] The magneto-optical recording medium of the present invention includes at least two layers of: a reproduction layer which is an in-plane magnetized film at room temperature but changes into a perpendicular magnetized film when it is heated; and a record layer which performs exchange coupling with the reproduction layer and which is always a perpendicular magnetized film at heated temperature as well as at room temperature.

[0017] For example, a perpendicular magnetized film made of an amorphous alloy of rare earth and iron-group metal, a garnet, Pt/Co, Pd/Co or the like may be used as the record layer. Moreover, owing to transmission of reproducing light, a material having the large Kerr rotation angle and the large Faraday rotation angle is more preferable.

[0018] The reproduction layer is required to move its direction of magnification at its high-temperature portion in a data reproducing laser spot from an in-plane direction to a direction perpendicular to a film surface. A magnetic material to be used for a magnetic layer of the reproduction layer may be one having perpendicular magnetic anisotropy by nature, which becomes an in-plane magnetized film under the influence of its own demagnetizing field attributed to large saturation magnetization Ms at room temperature but which becomes a perpendicular magnetized film when Ms is decreased in proportion to a temperature increase upon reproduction. A magnetic thin film having its Curie temperature or compensated temperature at a point slightly higher than the temperature of

reproduction may be used as such material. In particular, it is preferable to select one having the compensated temperature in the neighborhood of the temperature of reproduction, because its Kerr rotation angle is not decreased upon reproduction whereby sufficiently large reproduction signals can be obtained. In addition, it is preferable that the reproduction layer is made of a material having the large Kerr rotation angle and the large Faraday rotation angle.

[0019] In addition to the above-described reproduction layer and record layer, dielectrics such as SiN, AlOx and TaOx, and a metallic reflection layer such as Al, AlTi, AlCr, AlTa and Cu may be provided for increasing reproduction signals by interference effect. Furthermore, protective coating made of the above-described dielectric layer or macromolecular resin may be also provided as a protection film.

[0020] The inventor of the present invention has examined the process of magnetization transcription from the record layer to the reproduction layer, and has found out that the magnetization of the record layer was transcribed only within a heated portion in a laser spot, by using as the reproduction layer a magnetic layer which is an in-plane magnetized film at room temperature but that changes into a perpendicular magnetized film at high temperature. In this method, reproduction of the signals of which cycles are not higher than detection limit of light is effectuated without requiring an additional operation such as arranging the magnetization of the reproduction layer to a certain direction in advance.

[0021] A principle of a reproduction process of the present invention will be hereinafter described.

[0022] Data signals are recorded on a record layer of a magneto-optical recording medium shown in Fig. 1. Recording is executed either by modulating external magnetic fields while irradiating laser beams having power to render the record layer close to the Curie temperature, or by modulating laser power while applying magnetic fields in a recording direction after initializing magnetization to the same direction.

[0023] In this event, by deciding intensity of the laser beams in consideration of a linear velocity of the recording medium such that merely a predetermined area within a beam spot is rendered close to the Curie temperature of the record layer, a recording magnetic domain equal to a

diameter of the beam spot or less can be formed. As a result, the signals of which cycles are not higher than diffraction-limited of light become recordable.

[0024] Data reproduction is executed by continuous irradiation of laser beams for reproduction onto the medium and by detecting reflecting light or transmitting light from the recording medium. In this event, temperature of a portion of laser-beam irradiation is increased and temperature distribution on the medium forms a shape elongated toward a moving direction of the medium, with a portion in the beam spot being at high temperature, as shown in Fig. 3.

[0025] Incidentally, it is known that a main direction of magnetization is decided by an effective perpendicular magnetic anisotropy constant $K\perp$, defined by:

$$K\perp = Ku - 2\pi Ms^2$$

where Ms is saturation magnetization of a magnetic thin film and Ku is a perpendicular magnetic anisotropy constant. Here, $2\pi Ms^2$ denotes energy of demagnetizing fields.

[0026] As shown in Fig. 5, Ms of the reproduction layer is decreased upon reproduction due to a temperature increase. Accordingly, $2\pi Ms^2$ sharply drops as shown in Fig. 6, and a size relation with the perpendicular magnetic anisotropy constant Ku is inverted (the temperature of inversion is set as Tr), and the reproduction layer changes into a perpendicular magnetized film because of $K\perp > 0$. (Whereas Ku is also slightly decreased due to a temperature increase, such rate of decrease is generally small in comparison with $2\pi Ms^2$.)

[0027] In the meantime, since Ms is large in a portion at temperature on and below Tr, the equation $K\perp < 0$ is satisfied and thus the reproduction layer remains as the in-plane magnetized film.

[0028] In other words, if the intensity of the laser beams upon reproduction is set such that merely a high-temperature portion of the beam spot as illustrated in Fig. 3 is heated up to the temperature Tr or higher, then as shown in Fig. 2, only the high-temperature portion being a part of the beam spot of the reproduction layer changes into the perpendicular magnetized film, and a state is achieved in which other major parts remain as the in-plane magnetized film. Since the reproduction layer changed into the

perpendicular magnetized film is magnetically coupled with the record layer by exchange coupling, the signals on the record layer are transcribed to the reproduction layer. The transcribed magnetic signals are converted into optical signals by magneto-optical effect (the Kerr rotation angle or the Faraday rotation angle) of the reproduction layer and are detected.

[0029] As described above, in consideration of the face that an area of the high-temperature portion of the beam spot illustrated in Fig. 3 can be decided according to set intensity of the laser beams, transcription to the reproduction layer becomes feasible in respect of each recording bit unit of the signals recorded on the record layer, of which cycles are not higher than the diffraction-limited of light. Consequently, the signals of which cycles are not higher than the diffraction-limited of light can be reproduced without intersymbol interference.

[0030] Moreover, concerning reproduction, if temperature distribution is set such that a temperature Tt of an interface between the reproducing track and its adjacent track satisfies $Tt < Tr$, then a reproduction layer of the adjacent track does not change into a perpendicular magnetized film. Consequently, the signals recorded on a record layer of the adjacent track are not transcribed to the reproduction layer, whereby cross talks are completely eliminated. This aspect is illustrated in Fig. 4.

[0031] Note that description was made in the foregoing on a case where the reproduction layer and the record layer are magnetically coupled by exchange interaction. However, the reproduction layer and the record layer may be magnetically coupled by magnetostatic coupling upon reproduction.

[0032] The present invention will be hereinbelow described in further detail based on an experimental example. However, the present invention will not be limited by the following experimental example unless it exceeds the gist thereof.

(Experimental example 1)

[0033] A direct-current magnetron sputtering apparatus was fitted with targets severally made of SiN, Tb, Gd, Fe, Co and Al, and a glass substrate was fixed to a substrate holder. Then, vacuum pumping of a chamber was carried out with a cryopump until the chamber reached a high vacuum of 1×10^{-5} Pa or below.

[0034] While vacuum pumping, Ar gas was introduced into the camber up to 0.3 Pa, and then direct-current electric power was severally applied to the targets of Gd, Tb and Co, whereby a GdTbCo layer was deposited in a thickness of 800 Å on the glass substrate. Subsequently an alternating current was applied to the SiN target, whereby an SiN layer was deposited in a thickness of 800 Å as a protection layer. Composition of the GdTbCo layer was adjusted by varying power to the respective targets of Gd, Tb and Co during sputter deposition, and arrangement was made such that its compensated temperature became 180°C and its Curie temperature became 350°C or higher.

[0035] Moreover, reflecting the high Curie temperature, the Kerr rotation angle showed attenuation of within 10% from the value at room temperature even when the temperature was near 150°C. Measurement was carried out regarding an average turnover of the magnetic moment with respect to external magnetic fields magnetized perpendicularly to a film surface of the reproduction layer. And it was confirmed as shown in Fig. 8, that the film of the reproduction layer, which has had an in-plane direction of magnetization, was changed into a perpendicular magnetized film at a temperature near 100°C.

[0036] Next, a chamber similar to the foregoing except that a polycarbonate substrate provided with ϕ 30 mm pre-grooves was put on instead was subjected to high-vacuum pumping with a cryopump, and Ar gas was introduced up to 0.3 Pa in the chamber. An SiN layer was deposited in a thickness of 1000 Å in order to acquire antioxidation and interference effect on the substrate, and then a GdTbCo layer in a thickness of 200 Å as a protection layer and a TbFeCo layer in a thickness of 200 Å as a record layer were deposited. Thereafter, an SiN layer in a thickness of 300 Å and an Al layer in a thickness of 400 Å as a reflection layer were deposited in order to enhance the antioxidation and the interference effect. Deposition was continuously carried out in series without breaking the vacuum, and thus a magneto-optical recording medium composed of five layers as shown in Fig. 7 was made as one example of the present invention.

[0037] Each refractive index n of the SiN layers was adjusted to about 2.1, and composition of Tb, Fe and Co in the TbFeCo layer was adjusted to the proportions of 21 at%, 72 at% and 7 at%, respectively.

[0038] Next, recording and reproducing characteristics were measured by use of the magneto-optical recording medium.

[0039] NA of an objective lens of a measurement system was set to 0.55, and a laser wavelength was set to 780 nm. With recording power of 6.7 mW and a linear velocity of 5 m/sec, carrier signals in a range of 2 to 10 MHz were written on the record layer at intervals of 2 MHz by the magnetic field modulation method, and dependency of the C/N ratio (a ratio of carrier levels versus noise levels) on the recording frequency was investigated. The result is illustrated in Fig. 9.

(Example of comparative experiment)

[0040] A magneto-optical recording medium was made with a constitution similar to the example 1 except that the reproduction layer was removed so that the medium is composed of four layers. Dependency of the C/N ratio on the recording frequency was similarly investigated. The result is illustrated in Fig. 9.

[0041] It is learned from Fig. 9 that a good C/N ratio is obtainable even at a high recording frequency by adopting the method of the present invention.

[Effect of the invention]

[0042] By adoption of the magneto-optical recording medium and the reproduction method of the invention, reproduction of magnetic domains smaller than the diameter of the beam spot becomes feasible and cross talks were eliminated by use of a simple device without requirement of a initializing magnet (a conventional device), and high-density recording becomes achievable by improvements in track density and linear recording density.

[Brief description of the drawings]

[Fig. 1] Fig. 1 is a schematic view showing one example of film compositions of a magneto-optical recording medium of the present invention.

[Fig. 2] Fig. 2 is an explanatory drawing for showing a principle of a reproduction method of the magneto-optical recording medium of the present invention.

[Fig. 3] Fig. 3 is a view showing temperature distribution of a medium around a beam spot when the medium is moved.

[Fig. 4] Fig. 4 is a schematic view showing a state of emergence of magnetization transcription.

[Fig. 5] Fig. 5 is a view showing one example of temperature dependency of magnetization Ms and a performance index ($R\theta_k$) of the reproduction layer.
[Fig. 6] Fig. 6 is a view showing temperature dependency of $2\pi Ms^2$ and a perpendicular magnetic anisotropy constant Ku of the reproduction layer.
[Fig. 7] Fig. 7 is a view of film compositions of a magneto-optical recording medium in an example of the present invention.
[Fig. 8] Fig. 8 is a view showing an average turnover of the magnetic moment with respect to external magnetic fields applied perpendicularly to a film surface in an example.
[Fig. 9] Fig. 9 is a view showing dependency of C/N ratios on a recording frequency.

[Document type] Abstract
[Abstract]
[Object] To enable a magneto-optical recording and reproducing device used conventionally to reproduce signals of which cycles are not higher than diffraction-limited of light, and to effectuate improvements in linear density and track density.
[Constitution] Used is a magneto-optical recording medium composed of: a reproduction layer which is an in-plane magnetized film at room temperature but changes into a perpendicular magnetized film when it is heated, and a record layer made of a perpendicular magnetized film. Signal recording on the record layer is carried out, and then upon signal reproduction, magnetization of the record layer is converted into optical signals by means of magneto-optical effect and read out, while transcribing the magnetization to the reproduction layer.
[Selected drawing] Fig. 2